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Semi-Annual Status Report

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Investigation of the Basic Foundation of Masers and Lasers

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STATUS REPORT

This status report of work on laser theory during the first half of CY 1969 indicates the activities of each member of the group. These are to some degree carried out in cooperation with the Principal Investigator.

P. Berman

Berman received the Ph.D. degree in June 1969. A paper based on his thesis, entitled "The influence of resonant and foreign gas collisions on line shapes", has been accepted for publication in the Physical Review.

Future plans. Dr. Berman is remaining at Yale for a post-doctoral year, and will continue to work on the effects of collisions on laser operation. In particular he is interested in the fact that the van der Waals forces depend on which of the two laser states a and b is excited. Schematically the wave function of the laser atom is of the form

$$\psi(r,R,t) = \varphi_a(R,t)u_a(r) + \varphi_b(R,t)u_b(r)$$

where $u_a(r)$, $u_b(r)$ are stationary state eigenfunctions of the atomic electron for levels a and b, and R denotes the center of mass coordinate. The electric dipole moment of the atom depends on the simultaneous presence in the wave function of the $u_a(r)$ and $u_b(r)$ terms through integrals like

$$\int \varphi_a^*(R,t)\ \varphi_b(R,t)\ dR \quad .$$

The value of this integral will change during the scattering process, and will probably be reduced if the van der Waals forces are different for states and and b. It will be important for understanding realistic laser operation to learn how to deal with this problem.

M. Borenstein

M. Borenstein continued to work on pressure effects in lasers. He is considering van der Waals collisions between the laser and the perturber atoms. He is particularly interested in correlation effects between the phase changes and the deflections produced in the collisions, and is developing an unified theory of the two phenomena. He has also found how to analytically solve the Boltzmann integro-differential equation for a more general collision kernel than that considered by Gyorffy, Borenstein and Lamb (Phys. Rev. 169, 340 (1968)). This kernel contains several parameters, and can be made to closely resemble a quite realistic collision kernel. This should help to reduce the amount of numerical computation required to deal with the equations of the theory.

Future plans. Mr. Borenstein will continue his work in this field, and hopes to finish his thesis during the year.

L. Menegozzi

Dr. L. Menegozzi has been working on ring laser theory. The object is to develop a general description of mode competition phenomena observed in ring lasers. The computer program has been put into operation, and is able to determine the ring laser oscillation behavior for any selected parameters.

Future plans. Dr. Menegozzi is currently in the second year of a Fellowship from the Argentine National Research Council. He expects to return to Argentina during the next year. Before his return he will be engaged in writing a journal article on the above work on ring laser theory, suitable illustrated by computer runs for various interesting cases.

M. O. Scully

Professor M. O. Scully is continuing to cooperate on the quantum theory of the laser. The paper "Quantum theory of an optical maser. III. Theory of photoelectric counting statistics" has been published in the Physical Review, vol. 179, 368 (1969). A related article "Photoelectric effect without photons" by Lamb and Scully has been published in a Jubilee volume honoring Professor Alfred Kastler, entitled "Polarization, matière et rayonnement", Presses Universitaires de France, Paris, 1969.

Future plans. Professor Scully will be on leave from M.I.T. during 1969-70 at the University of Arizona, Tucson. Despite the distance, it is hoped that some progress can be made on the unfinished work of mutual interest. This will be contained in papers Parts IV, V and VI of the Quantum theory of an optical maser series.

Y. K. Wang

Y. K. Wang has been considering problems of transient behavior in the fully quantum mechanical laser. He is investigating ways of dealing efficiently with the many differential equations for the time development of the density matrix ρ_{nm}.

Future plans. See above.

M. Spencer

M. Spencer has developed the theory required to treat the mode competition phenomena when two similar gas lasers are coupled together. It is desired to learn the conditions for frequency locking. The problem also has an instructive relationship to the problem (Part VI) of Scully and Lamb, more fully described in the Semi-Annual Status Report for the first half of CY 1967.

Future plans. The problem of two coupled lasers is surprisingly complicated, much more so than the normal case of two mode operation met in Fabry-Perot lasers where two longitudinal modes are in competition. Spencer will investigate the equations using analytical methods where possible, and computer solutions where necessary. It is possible that some interesting features bearing on frequency control will emerge from the work.

A. Icsevgi

A. Icsevgi received the Ph.D. degree in June 1969. A version of his thesis "Propagation of light pulses in a nonlinear laser amplifier" has been accepted for publication in the Physical Review. He is now extending the work to apply to self-pulsing operation in lasers, both of the Fabry-Perot and ring types.

Future plans. One of the strange astrophysical phenomena observed in recent years is the microwave radiation from the free radical molecule OH. This radiation has four components 1.612, 1.665, 1.667 and 1.77 x 10^9 cps. It was first observed at the Millstone-Haystack antennae of the Lincoln Laboratories of M.I.T. A radio region in Casseopeia shows a region of OH emission of angular diameter less than 5' of arc. The emission line has a complicated structure suggesting emission from several small regions having different relative velocities. It is estimated that the effective black body temperature for the source is 1000°K or more. However, the individual components of the emission line are only 10^3 cps wide, implying an 100°K OH temperature. The really remarkable aspect of the OH emission is the 90 - 100% circular polarization of the various components of the microwave line. Some times the polarization is right handed, and some times it is left handed. Strange intensity ratios are observed, and these change with time. It has been suggested by a number of people that the intense emission may be the result of maser action pumped by 3080Å radiation by a hot star near the OH region. The polarization phenomena observed are similar to those observed in Zeeman lasers, and can probably be explained as due to mode competition in the non-linear active medium.

Such phenomena present an interesting theoretical problem. Presumably laser action is involved. The kind of laser simplest to consider has mirrors. There are no mirrors in the OH region. It seems to be worthwhile to consider the problem using the techniques Icsevgi has developed for following the time development of pulses in a laser amplifier. Presumably the OH radiation which reaches us has started from noise, and has been amplified as it passes through an active medium. Icsevgi will apply his theory to find out how noise pulses propagate in his amplifying medium. It may be that the temporal variation of the signal will be similar to those observed. The medium is steadily being pumped, but when a favorable noise pulse is amplified, the medium becomes saturated, and has to rest for a time before it recovers the ability to amplify. Some way to relate the three dimensional nature of the real problem to the one dimensional theory will have to be found. This promises to provide a challenging and interesting problem.

S. Stenholm

Dr. S. Stenholm returned to Finland last year. Owing to a clerical error in the editorial offices of the American Institute of Physics the publication of the article "Semi-classical theory of a high intensity laser" in the Physical Review was delayed several months. It has now appeared in vol. 181, p. 618 (1969).

Future plans. Dr. Stenholm has a manuscript in progress dealing with an extension of the above paper.